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(R) Degradation Limits of Hydrocarbon-Based Hydraulic Fluids, MIL-PRF-5606, MIL-PRF-83282, and MIL-PRF-87257 Used in Hydraulic Test Stands

RATIONALE

This document is being revised to update the specification numbers for the fluids, to add MIL-PRF-87257, and to delete the non-aerospace rust inhibited hydraulic fluids. In addition, a maximum allowable limit for barium is being added due to the problems experienced when barium gets introduced to the aircraft hydraulic system.

1. SCOPE

This SAE Aerospace Information Report (AIR) presents data on normally accepted changes in physical properties and contamination levels for military hydraulic fluids used in hydraulic test stands. This information is of importance to all users of hydraulic test stands to assure the performance data obtained on these test stands for specific components will not be adversely affected by excessive changes in fluid properties or contamination levels. The data pertains to fluids conforming to specifications MIL-PRF-5606, MIL-PRF-83282, and MIL-PRF-87257. The guidelines incorporated in the AIR are the general consensus values of knowledgeable professionals. However, the experience and judgment of engineers and operators responsible for the equipment must be relied upon to determine when the hydraulic fluid is to be replaced.

1.1 Purpose

The purpose of this report is to offer guidelines for deciding when the respective fluid has degraded to an extent that warrants replacement in hydraulic test stands. The most sensitive hydraulic components in systems using the subject fluids will dictate the limits of contamination or degradation permitted for each case. The guidelines incorporated in the AIR are the general concerns of knowledgeable professionals. However, the experience and judgment of engineers and operators responsible for the equipment must be relied upon to determine when hydraulic fluid is to be replaced.

2. APPLICABLE DOCUMENTS

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

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2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

AS4059 Aerospace Fluid Power - Cleanliness Classification for Hydraulic Fluids

2.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM D92 Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester

ASTM D93 Standard Test Methods for Flash Point by Pensky-Martens Closed Cup Tester

ASTM D97 Standard Test Method for Pour Point of Petroleum Products

ASTM D445 Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)

ASTM D664 Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration

ASTM D2709 Standard Test Method for Water and Sediment in Middle Distillate Fuels by Centrifuge

ASTM D5185 Standard Test Method for Determination of Additive Elements, Wear Materials, and Contaminants in Used Lubricating Oils and Determination of Selected Elements in Base Oils by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)

ASTM D6304 Standard Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration

ASTM D6443 Test Method for Determination of Calcium, Chlorine, Copper, Magnesium, Phosphorus, Sulfur, and Zinc in Unused Lubricating Oils and Additives by Wavelength Dispersive X-ray Fluorescence Spectrometry (Mathematical Correction Procedure)

ASTM STP No. 382 "The Effects of Polymet Degradation on Flow Properties of Fluids and Lubricants," American Society for Testing and Materials, Philadelphia

2.3 U.S. Government Publications

Available from DLA Document Services, Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6396, http://quicksearch.dla.mil/.

MIL-PRF-5606 Performance Specification Hydraulic Fluid, Petroleum Base; Aircraft, Missile, and Ordnance

MIL-PRF-83282 Performance Specification Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Metric, Nato Code Number H-537

MIL-PRF-87257 Performance Specification Hydraulic Fluid, Fire Resistant; Low Temperature Synthetic Hydrocarbon Base, Aircraft and Missile

2.4 STLE Publications

Available from Society of Tribologists and Lubrication Engineers, 840 Busse Highway, Park Ridge, IL 60068-2302, Tel: 847-825-5536, www.stle.org.

Lipp, L.C., "Halogenated Solvent-Induced Corrosion in Hydraulic Systems," Preprint No. 78-AM- 42A, American Society of Lubrication Engineering, Order of Precedence

3. MIL-PRF-5606 FLUID CHARACTERISTICS

Although hydraulic fluid manufacturers are reluctant to reveal the exact formulas of their products, the approximate compositions of these fluids are well known, and numerous details can be found in the texts of the actual specifications. MIL-PRF-5606 is based on a low-viscosity naphthenic petroleum base stock with a flash point of around 82 °C (closed cup). This base stock is thickened to the required viscosities by the addition of polyacrylate viscosity index improver. The fluids must supply a certain degree of antiwear protection, which is achieved by the addition of approximately 0.5% tricresyl phosphate. Up to 2% antioxidant may be present. Until recently, no pour point depressants could be used; however, the latest E-revision of MIL-PRF-5606 permits them. The fluid must meet limits on the amount of particulate contamination present.

Some of the required properties for new fluid are summarized in Table 1:

TABLE 1 - PROPERTIES OF MIL-PRF-5606H

	MIL-PRF-5606H
Viscosities (centistokes)	
100 °C	4.90 minimum
40 °C	13.2 minimum
-40 °C	600 maximum
-54 °C	2500 maximum
Flash Point, ASTM D93	82 °C minimum
Acid or Base No. (ASTM D664)	0.2 maximum
Water (Karl Fischer)	100 ppm maximum

Along with the degree of particulate contamination, these are properties likely to be monitored by the hydraulic fluid user.

3.1 Change in Fluid Properties of MIL-PRF-5606 During Use

3.1.1 Viscosity

The use of polyarcrylate viscosity index improvers in these fluids is necessary in order to achieve the desired viscosities, but their presence creates the problem known as shear instability. Under conditions of high shear, such as are normally found in a high pressure aircraft hydraulic system pump, the acrylate polymer is gradually sheared down in to lower molecular weight fragments, with a resulting loss in fluid viscosity at operating temperature. Actually, both temporary and permanent losses in viscosity occur. In the region of high shear, there is often a temporary loss with the result that the pump or component does not see the same fluid viscosity that would be observed in the laboratory. Since a loss in fluid viscosity may adversely affect the lubricating properties of the fluid, this form of shear instability must be considered by design engineers, however, since it is only temporary, it would not be observed by personnel monitoring the fluid viscosity. The permanent viscosity loss, on the other hand, must definitely be considered in deciding when the fluid is to be changed out. In one study, samples of used MIL-PRF-5606, drained from operational F-4 aircraft by Wright-Patterson Air Force Base personnel, were found to have 40 °C viscosities ranging from 13.76 to 12.12 centistokes. In many cases, the viscosity loss is even worse, and 40 °C viscosities as low as 10 centistokes are not uncommon. Some hydraulic systems are designed in such a way that the effects of such a viscosity change are minimal; others, however, are more sensitive.

Oxidation can also affect the viscosity of these fluids. A slight degree of fluid oxidation may result in a viscosity increase; an excessive degree of oxidation may result in polymer degradation, with a viscosity loss similar to that caused by mechanical shear. If the system is open or vented to the atmosphere, some of the napthenic base oil, which is relatively low boiling, may evaporate, and the remaining fluid, which contains all the polymer, will increase in viscosity. Occasionally, a "hot spot" in the system may cause enough of the base oil to evaporate so that the polymer is actually deposited in a solid or semisolid state, causing plugging of filters and freeze-up of valves and servos. Finely dispersed metal particles in hydraulic fluids may act as a catalyst to oxidize the fluid.

3.1.2 Acid Number

Fluid degradation is often accompanied by an increase in the acid number. Oxidation, for example, converts susceptible hydrocarbon components of the base oil into carboxylic acids, which may cause corrosion of susceptible metal components. How much acidity can be tolerated will again depend upon the configuration and metallurgy of the individual system. A build-up of acid number would not be expected during use. A high acid number in MIL-PRF-5606 would indicate that unusually high temperatures (>135 °C) are present somewhere in the test stand.

3.1.3 Flash and Fire Point

One of the major drawbacks of MIL-PRF-5606 is the low flash point of the base stock. A further drop in flash point during use would obviously be undesirable, and would probably reflect contamination by some low-boiling flammable solvent. An increase in the flash point could indicate evaporative loss of base oil, or possible excessive contamination with nonflammable solvents such as trichlorotrifluorethane or trichloroethylene.

3.1.4 Water Content

The water content is controlled for new fluids to <100 ppm by weight by the specifications. MIL-PRF-5606 is not particularly hygroscopic, but inasmuch as it is not a rust-inhibited fluid, an increase in moisture content beyond the saturation limits could be more serious. The water saturation concentration for MIL-PRF-5606, the concentration at which free water is present in the fluid varies slightly, but is generally around 250 ppm by weight. Gross amounts of water in hydrocarbon hydraulic fluids are usually undesirable and should be removed by a fluid purifier or by draining the contaminated fluid from the system and flushing with new fluid.

4. MIL-PRF-83282 AND MIL-PRF-87257 FLUID CHARACTERISTICS

Although MIL-PRF-83282 and MIL-PRF-87257 were designed for hydraulic systems that previously used MIL-PRF-5606, these fluids are significantly different from the petroleum-based fluid discussed in Section 3. MIL-PRF-83282 and MIL-PRF-87257 are formulated with a polyalphaolefin synthetic hydrocarbon base stock. These specifications require that these base stocks have flash points of 205 and 160 °C (open cup) respectively and fire points of 245 and 170 °C (open cup) respectively. Thus, these fluids are significantly less flammable than MIL-PRF-5606 and are often referred to as "fire resistant." In order to meet the seal swell and the low temperature viscosity requirements, the specifications permit the addition of blending fluids such as diesters in concentrations up to 33%. Tricresyl phosphate is recommended to meet the antiwear requirements, and oxidation inhibitors of the phenolic type are specified in amounts not to exceed 3 and 1%, respectively. Viscosity index improvers and pour point depressants are not permitted in either fluid. Both fluids must meet particle count requirements defined in AS4059.

Some of the required properties for MIL-PRF-83282 and MIL-PRF-87257 fluids are summarized below:

TABLE 2 - PROPERTIES OF MIL-PRF-83282D AND MIL-PRF-87257B

	MIL-PRF-83282D	MIL-PRF-87257B
Viscosities, centistokes (ASTM D445)		
100 °C	3.5 minimum	2.0 minimum
40 °C	14.0 minimum	6.7 minimum
-40 °C	2200 maximum	550 minimum
Flash/Fire Points (ASTM D92)	204.4 °C/245 °C minimum	160 °C/170 °C minimum
Water (Karl Fischer) (ASTM D6304)	100 ppm maximum	100 ppm maximum
Pour Point (ASTM D97)	-55 °C maximum	-60 °C maximum
Acid or Base Number(ASTM D664)	0.10 maximum	0.2 maximum

4.1 Change in Fluid Properties of MIL-PRF-83282 and MIL-PRF-87257 During Use

4.1.1 Viscosity

Neither of these fluids contains a viscosity index improver and, as a consequence, neither is subject to the shear instability and viscosity loss observed in MIL-PRF-5606. Oxidation of MIL-PRF-83282 and MIL-PRF-87257 normally leads to an increase in viscosity, although under ordinary operating conditions the increase will be low. Finely dispersed metal particles may act as a catalyst to oxidize the fluid. A decrease in viscosity, on the other hand, usually indicates the presence of some low-viscosity contaminant such as fuel or solvent.

4.1.2 Acid Number

Degradation of the two synthetic hydrocarbon fluids may be accompanied by an increase in acid number. Oxidation is one cause; but, with MIL-PRF-83282 and MIL-PRF-87257, the possibility of acid generation through hydrolysis must be taken into account. Both fluids conventionally contain substantial amounts (up to 33%) of lubricant diesters, in order to achieve the desired low temperature and seal swell characteristics. Esters are manufactured by the reaction of alcohols and acids, with water being formed as a byproduct. However, at high temperatures, the reverse reaction can also occur; esters can react with water to form alcohols and acids, with a resultant increase in acid number. This reaction, called hydrolysis, is extremely slow, and rarely presents a problem except where gross contamination by water is a factor.

4.1.3 Flash and Fire Points

The relatively high flash and fire points of MIL-PRF-83282 and MIL-PRF-87257, compared to those of MIL-PRF-5606 have been a major reason for the increased use of synthetic hydrocarbon fluids. In the field, the changeover of aircraft hydraulic systems from MIL-PRF-5606 to MIL-PRF-83282 and MIL-PRF-87257 was most frequently carried out by simple attrition, with the synthetic base fluid being added as make-up when the level of MIL-PRF-5606 became low. Conversion of aircraft from MIL-PRF-83282 to MIL-PRF-87257 or vice versa by attrition is also recommended to save waste fluid and maintenance hours. Thus, there are many aircraft flying with mixtures of MIL-PRF-83282 or MIL-PRF-87257 and MIL-PRF-5606 having flash and fire points intermediate between the two. When MIL-PRF-83282 or MIL-PRF-87257 are the only fluids in the system, lower flash points would reflect contamination by low-boiling solvents, fuel or MIL-PRF-5606.

4.1.4 Water Content

The water content of the two fluids is controlled by the specifications at 100 ppm maximum for MIL-PRF-83282 and MIL-PRF-87257. Diesters are slightly hygroscopic, and tend to pick up moisture if drums or containers are allowed to remain open for extended periods of time prior to filling a system. Compressed air if used for reservoir super charge may also be a source of moisture. Since neither MIL-PRF-83282 nor MIL-PRF-87257 contain rust inhibitors, the presence of excess moisture could present a problem for susceptible metal parts and, of course, over long periods of time, the possibility of hydrolysis must also be considered. Ice crystals can clog small orifices and filter elements in hydraulic systems.

5. EFFECTS OF CONTAMINATION

Contamination of the fluids can occur from many sources. The effects of moisture have already been discussed in 3.1.4 and 4.1.4. This section will deal with particulate and solvent contamination.

5.1 Particulate Contamination

Modern hydraulic systems are extremely sensitive to the presence of small particles. Certain systems components have tolerances in micrometer range and can be plugged or scored by microscopic-sized debris in the fluid. Particles may also lodge in seals and gaskets where they can act as abrasives on moving parts. All three fluids when originally packaged meet rigid particle count standards, but this cleanliness is compromised as soon as the fluid containers are open. Once in the system, wear debris such as particles of metal and seal material rapidly reduce the cleanliness of the fluid. In-line filters partly compensate for this problem, but, nonetheless, an increase in particulate contamination is a common cause for fluid change-out.

5.2 Solvent Contamination

Two types of solvents have traditionally been used in flushing hydraulic systems and cleaning components, and both periodically find their way into hydraulic fluid. Hydrocarbon solvents such as Federal Specification P-D-680, if present in sufficient quantities, can lower the flash and fire points of the fluid. They may also cause excessive swell of seals and gaskets. Chlorinated solvents such as trichlorotrifluoroethane and trichlorethylene can cause serious corrosion and sludging problems in hydraulic systems. There are well documented cases of valve sticking in MIL-PRF-5606 fluid, which were eventually traced to the presence of chlorinated solvent and moisture at elevated temperature. Gelatinous sludges containing chlorine have been reported in systems where MIL-PRF-83282 had been contaminated with trichlorotrifluoroethane. As a result of this adverse effect on hydraulic systems as well as environmental reasons, the Air Force has moved away from the use of chlorinated solvents in servicing hydraulic systems, but these solvents still persist in many industries. The amount of chlorinated solvent that can be tolerated in a fluid without causing corrosion and sludge is not known with any degree of certainty; it depends to some extent on the system design characteristics. Contamination by solvent is another common cause for fluid change-out. Chlorinated solvent contamination removal from the fluid by purification is an alternative to fluid change-out. The use of vacuum dehydration equipment, has, in many cases, provided a suitable alternative to fluid replacement.

4.4 Rust Inhibitor Contamination

The primary rust inhibitor used in military hydraulic fluids, MIL-PRF-6083 and MIL-PRF-46170 is barium dinonylnaphthalene sulfontate. When this rust inhibitor has been accidently introduced into aircraft hydraulic systems, problems with components have been observed. These include stuck valves and premature filter change requirements. This rust inhibitor cannot be removed by fluid purifiers and when barium is found in MIL-PRF-5606, MIL-PRF-83282 or MIL-PRF-87257 in concentrations exceeding 20 ppm, problems in aircraft hydraulic systems have been experienced. This is why MIL-PRF-6083 and MIL-PRF-46170 are prohibited from being used in aircraft component storage and hydraulic systems. However, there is the possibility that barium contamination can still be present in some systems and this contamination can be introduced into a test stand. For this reason, a maximum allowable barium limit has been established for the fluids in test stands.

The recommended maximum allowable limit for the test stands is 15 ppm of barium. When the rust inhibitor content has been kept below a 20 ppm limit, no problems have been experienced. Because there is still the possibility that trace amounts of MIL-PRF-6083 and MIL-PRF-46170 can still exist in hydraulic systems it is important to guard against contaminating the test stand fluid and it is important to analyze the test stand fluid to ensure that no barium contamination is present in excess of 15 ppm.

Land based military vehicles still use MIL-PRF-6083 and MIL-PRF-46170 and it is important that components from land based systems are not tested on the same test stands as aerospace components. If this occurs, the test stand must be flushed until the barium concentration in the fluid in the reservoir is much lower than 15 ppm before aerospace components can be mounted for testing.

6. RECOMMENDATIONS-SUGGESTIONS FOR PURIFYING OR CHANGING OUT A HYDRAULIC FLUID

It should be noted again that there are no absolute rules for determining when a hydraulic fluid has become sufficiently degraded or contaminated and can no longer perform satisfactorily in a given system. It is better, however, to be conservative when a doubt exists. If fluid purifiers can remove the contaminants that exceed recommended limits, their use to remove the contaminants, thereby restoring the fluid to useable condition, is recommended. However, if the contaminants present cannot be removed by fluid purifiers, the fluid must be removed, the system flushed and new fluid charged into the system. Usually the cost of the fluid is considerably less than the cost of the hydraulic system, and it is better to sacrifice a few gallons of fluid that may still be usable than to risk failure of a key pump, valve, or servo. An alternate action would be to condition the fluid with purification equipment. With that in mind, the following guidelines summarized in the attached Tables 3 and 4 are offered.

6.1 MIL-PRF-5606

MIL-PRF-5606 should be changed out when the viscosity at 40 °C drops to 10 centistokes, or when the acid number has increased by 0.2 over its original value. Usually substantial degradation will have occurred by the time either of these two limits is met. A drop in the flash point below specification limits is also cause for changing out the fluid. An increase in viscosity or flash point could signal evaporation of the base oil. A change in system design or operating temperature, rather than a change of fluid, is suggested here. When the moisture content of MIL-PRF-5606 exceeds 150 ppm, the fluid should be changed or purified. The total chlorine content, an indication of the amount of chlorinated solvent contamination, should be kept below 200 ppm. Purification to undersaturate the fluid with respect to chlorine and water contamination is a safeguard.

6.2 MIL-PRF-83282 and MIL-PRF-87257

MIL-PRF-83282 and MIL-PRF-87257 should be changed out when the viscosity at 40 °C has increased by 10%, or when the acid number has increased by 0.2 over the original values. A drop in the flash point below the specification limits is also cause for change-out. Any significant decrease in the fluid viscosity at 40 °C, for example, 15% is usually an indication of solvent contamination and the fluid should be changed promptly or purified if the contaminant can be removed by purification. For MIL-PRF-83282 and MIL-PRF-87257, a moisture content above 300 ppm is grounds for purification or removal. The total chlorine content, an indication of the amount of chlorinated solvent contamination, should be kept below 200 ppm.

6.3 Particulate Contamination

The tendency to generate debris that shows up as particulate contamination in the hydraulic fluid varies considerably from one hydraulic system to another. Likewise, the sensitivity of individual systems to the degree of particulate contamination in the fluid differs greatly. A rapid increase in differential pressure across an in-line filter is an indication that the fluid is excessively contaminated with particulate matter and further analysis of the fluid is recommended. In this area, the individual must, to a large extent, establish his own guidelines as to when the hydraulic fluid is excessively contaminated. Particulate contamination can generally be effectively reduced to acceptable levels by purification.

6.4 Purification of the Fluid Versus Changing Out the Fluid

Whenever possible, purification of the contaminated hydraulic fluid is preferred over changing out the fluid. This is recommended both from environmental and cost savings aspects. Changing out the hydraulic fluid can require up to four test stand volumes of hydraulic fluid which requires not only the purchase of the new fluid, but also requires that the contaminated hydraulic fluid be disposed of. On the other hand, purification can be accomplished by processing the contaminated hydraulic fluid with a portable fluid purifier which eliminates the need for procurement of new fluid and disposal of the contaminated fluid. There are some contaminants that cannot be removed by purification which then necessitates fluid change out. Fluid purifiers can readily remove volatile and particulate contaminants. However, soluble, low volatility contaminants such as fuel, rust inhibitors, jet engine oil, etc., cannot be removed by purifiers.

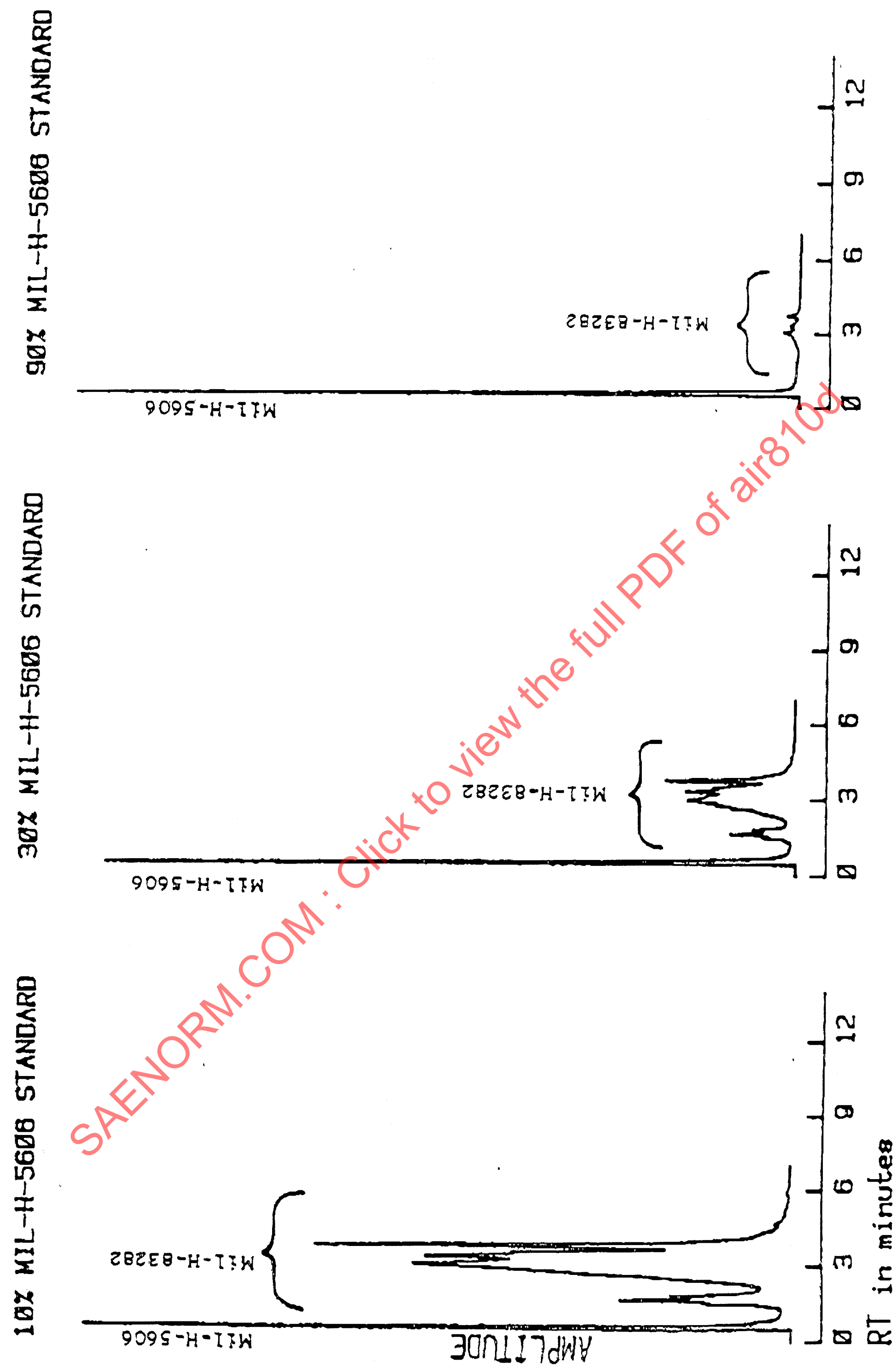

FIGURE 1 - CAPILLARY GAS CHROMATOGRAMS (FID)

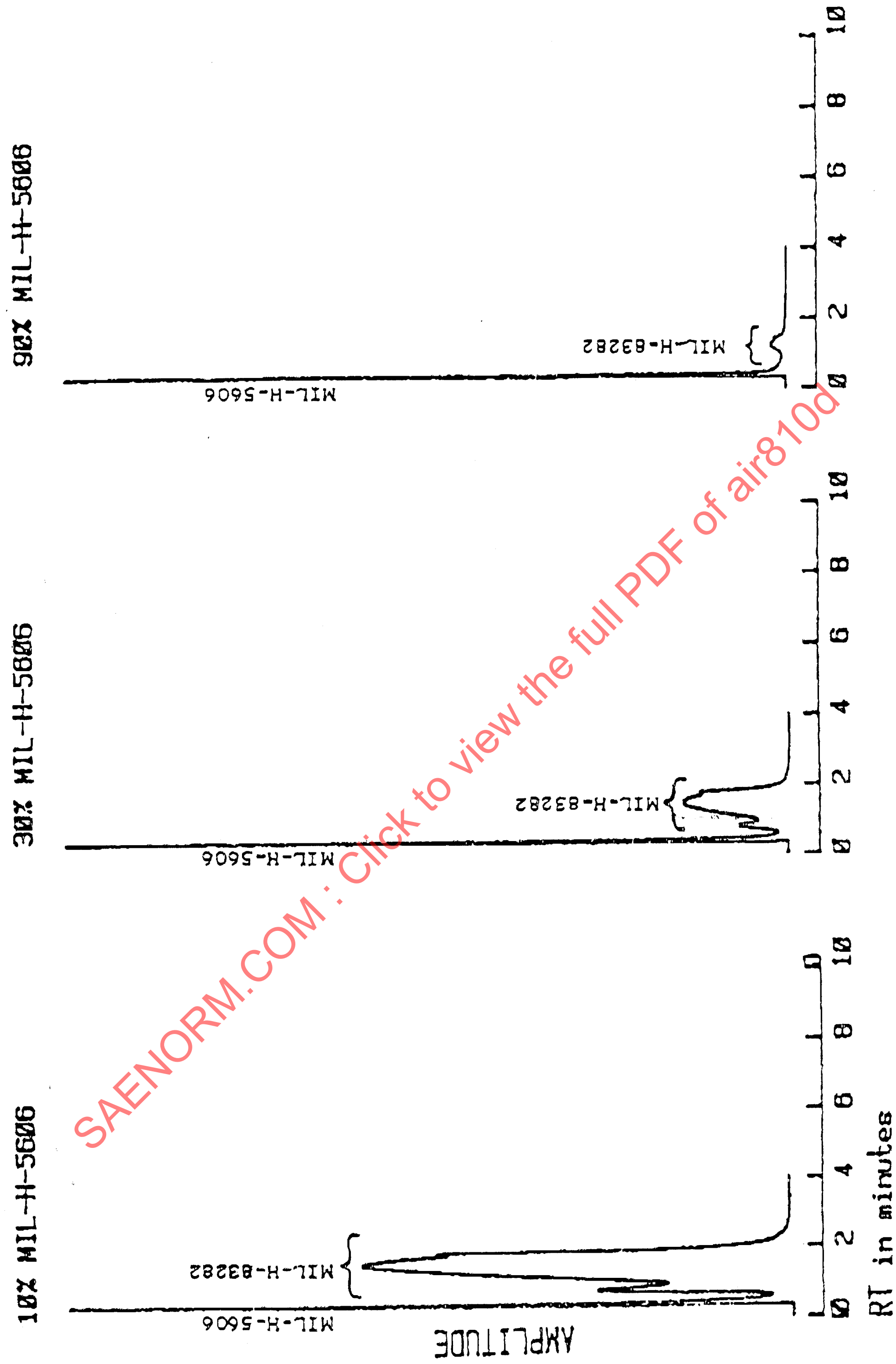

FIGURE 2 - GAS CHROMATOGRAMS (FID) PACKED COLUMN

TABLE 3A - MIL-PRF-83282 HYDRAULIC FLUID CHARACTERISTICS AND SUGGESTED USE LIMITS

Property	Test Method	Unit & Limit	New Fluid	In-Service Limit
Viscosity	ASTM D445	Centistokes, Min @ 40 °C	14	+10, -15%
Flash Point	ASTM D92 (Open Cup)	°C, Min	205	205
Acid Number	ASTM D664	mg KOH/Gram Max	0.10	0.30
Total Water	ASTM D6304 (Karl Fischer)	PPM Max	100	300
Free Water	ASTM D2709 (Centrifuge)	Percent By Volume, Max	None	No Measurable Free Water (<0.01%)
Total Chlorine	ASTM D6443 (XRF)	PPM Max	50	200
Barium Content	ASTM D5185 (ICP-AES)	PPM Max	10	15
Particulate Contamination	ARP598 Counter Automatic	Max Count Per 100 mL Sample Size Range Micrometers	AS4059 Class 4-5	AS4059 Class 8
		5-15	10K	64K
		16-25	1K	11.4K
		26-50	150	2025
		51-100	20	360
		Over 100	5	64

TABLE 3B - MIL-PRF-87257 HYDRAULIC FLUID CHARACTERISTICS AND SUGGESTED USE LIMITS

Property	Test Method	Unit & Limit	New Fluid	In-Service Limit
Viscosity	ASTM D445	Centistokes, Min. @ 40 °C	6.7	+10, -15%
Flash Point	ASTM D92 (Open Cup)	°C, Min Type I	160	160
Acid Number	ASTM D664	mg KOH/Gram Max	0.20	0.40
Total Water	ASTM D6304 (Karl Fischer)	PPM Max	100	300
Free Water	ASTM D2709 (Centrifuge)	Percent By Volume, Max	None	No Measurable Free Water (<0.01%)
Total Chlorine	ASTM D6443 (XRF)	PPM Max	50	200
Barium Content	ASTM D5185 (ICP-AES)	PPM Max	10	15
Particulate Contamination	ARP598 Counter Automatic	Max Count Per 100 mL Sample Size Range Micrometers	AS4059 Class 4-5	AS4059 Class 8
		5-15	10K	64K
		16-25	1K	11.4K
		26-50	150	2025
		51-100	20	360
		Over 100	5	64

TABLE 4A - MIL-PRF-5606 HYDRAULIC FLUID CHARACTERISTICS AND SUGGESTED USE LIMITS

Property	Test Method	Unit & Limit	New Fluid	In-Service Limit
Viscosity	ASTM D445	Centistokes, Min @ 40 °C	13.2 Min	10.0 Min
Flash Point	ASTM D92 (Open Cup)	°C, Min	82	82
Acid Number	ASTM D664	mg KOH/Gram Max	0.20	0.40
Total Water	ASTM D6304 (Karl Fischer)	PPM Max	100	150
Free Water	ASTM D2709 (Centrifuge)	Percent By Volume, Max	None	No Measurable Free Water (<0.01%)
Total Chlorine	ASTM D6443 (XRF)	PPM Max	50	200
Barium Content	ASTM D5185 (ICP-AES)	PPM Max	10	15
Particulate Contamination	ARP598 Counter Automatic	Max Count Per 100 mL Sample Size Range Micrometers	AS4059 Class 45	AS4059 Class 8
		5-15	10K	64K
		16-25	1K	11.4K
		26-50	150	2025
		51-100	20	360
		Over 100	5	64

7. NOTES

7.1 A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

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COMMITTEE A-6, AEROSPACE ACTUATION, CONTROL AND FLUID POWER SYSTEMS